BIOPOTANTIAL INSTRUMENTATION SET

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Abstract: In this study, a biological signal acquisition and processing set has been designed and realized. The set can be used in teaching basic principles in recording and analizing of biological signals. This set can be used in biomedical electronics engineering and biomedical technology laboratories. The set is especially helpful to teach how the biological signals are acquired and processed. ECG and EMG signals can be selected, amplified, filtered and transferred to the monitoring devices with this set while patient safety is provided. There are a number of connection points in the set for observing the signals at various levels. Students can make measurements at each of these steps with the connection probes outside the set. The output signals can be observed using an oscillascope. They can also be observed from a PC monitor with an electronic card connected to ISA bus.
***Keywords* - Biopotantial, Instrumentation, Experiment Set**

1. Sources and Types of Biological Signals:

The basic building blocks of human body are cells. When electrodes are placed inside and outside a cell without affecting physiology of the cell, a voltage between –50 and –100 mV is measured. This voltage is called "Membrane Potential". Source of this membrane voltage is the difference between the concentrations of K^+ , Na^+ ve Cl^- ions inside and outside the semi-permeable membrane.

As stated by Goldman, the membrane potential while the cell is at rest can be calculated by the formula[1],

$$V_m = -\frac{kT}{q}\ln\left(\frac{P_K[K^+]_i + P_{Na}[Na^+]_i + P_{Cl}[Cl^-]_O}{P_K[K^+]_O + P_{NA}[Na^+]_O + P_{Cl}[Cl^-]_i}\right) \qquad [1]$$

Vm , in this formula, represents the potential difference between inside and outside the cell, in mV.

$[CC]_i$ is the concentration of the ion CC inside the cell in mmol/litre.

[CC]o is the concentration of the ion CC outside the cell in mmol/litre.

P_{CC} : Membrane permeability for CC ion cm/s

k : Bolttzmann constant, 1.38 10^{-23} J/K

T : absolute temperature in K

q : electric charge of a proton, 1.602 10^{-19} C

Biopotentials are electrical potentials that appear with the currents that occur with the flow of ions inside a biological structure. The flow occurs with the activation of the excitable cells in nerve, muscle and seceration gland. These excitable cells can generate and propagate action potentials when they are excited with electrical stimulation of the membrane, chemical effects that change permeability of Na, heat effects or mechanical effects. The potential inside the cell is more negative at rest. However, when the cell is excited, Na permeability of the membrane increases quickly for a short period of time. The negative polarity disappear for a while. The potential inside the cell becomes even positive. This is called *depolarization.* Return of the cell to its stable state is called repolarization. Graph of an action potential is shown in Figure-1.

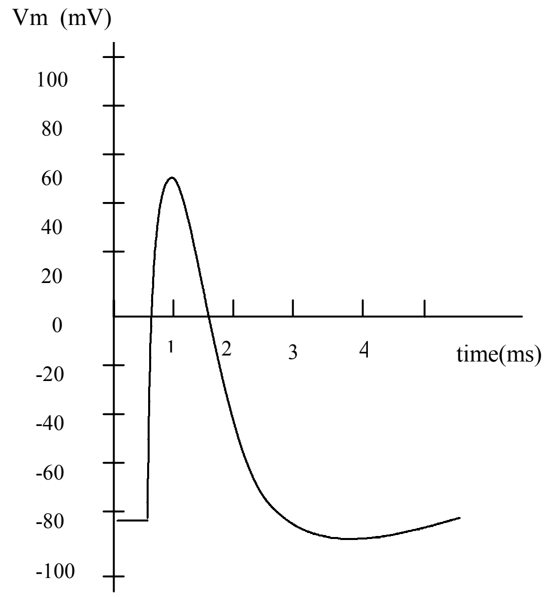

Figure 1:Action potential[4]

Report Documentation Page

Report Date	Report Type	Dates Covered (from... to)
25OCT2001	N/A	-

Title and Subtitle Biopotantial Instrumentation Set	**Contract Number**
	Grant Number
	Program Element Number
Author(s)	**Project Number**
	Task Number
	Work Unit Number
Performing Organization Name(s) and Address(es) Vocational School of Biomedical Technology , Baskent University, Ankaral, Turkey	**Performing Organization Report Number**
Sponsoring/Monitoring Agency Name(s) and Address(es) US Army Research Development & Standardization Group (UK) PSC 802 Box 15 FPO AE 09499-1500	**Sponsor/Monitor's Acronym(s)**
	Sponsor/Monitor's Report Number(s)

Distribution/Availability Statement
Approved for public release, distribution unlimited

Supplementary Notes
Papers from the 23rd Annual International Conference of the IEEE Engineering in Medicine and Biology Society, October 25-28, 2001, held in Istanbul, Turkey. See also ADM001351 for entire conference on CD-ROM., The original document contains color images.

Abstract

Subject Terms

Report Classification unclassified	**Classification of this page** unclassified
Classification of Abstract unclassified	**Limitation of Abstract** UU

Number of Pages
4

Table 1. Biopotentials/Physiological signals [2]

Biopotential/Physiological signal	Mesuarement Range	Frequence Range (Hz)
Electrocardiography (ECG)	0.5-4 mV	0,01-250
Electroencephalograpgy (EEG)	5-300 µV	dc-150
Electrogastrography (EGG)	10-1000 µV	dc-1
Electromyography (EMG)	0.1-5 mV	dc-10K
Electronerography (ENG)	10 µV-3mV	dc-10K
Elektro-oculography (EOG)	50-3500 µV	dc-50
Elektroretinography (ERG)	0-900 µV	dc-50

Biopotential signals are generated in human body as the organs do their routine tasks. Recording and analyzing these signals help us obtain clues about health and performance of the organs. Biological signals which are generated with the operation of the some of the organs are listed on Table 1.[2]

2. Technical Features

Block diagram of the experiment set developed is shown in Figure 2. The set has been designed to record and display ECG signals as well as EMG signals taken by needle or surface electrodes.

The input circuits are protected against the high voltage that may be generated by a defibrilator. The protection circuits contain 80V neon lamps as well as diodes connected in series with opposite polarity. These diodes limit the input voltage around the supply voltage. The input signals are high pass filtered with a –40 dB passive filter to eliminate the components with frequencies higher than the maximum frequency component in the input signals. To protect patient bodies from a current through their body, a buffer block is used. The buffer block has an impedance around 10^{12} Ω which is much higher than the impedances of the electrodes. 1 % tolerance type resistors are used in differential amplifiers so that potential differences caused by differences in resistance values are not generated.

EMG signals, on the other hand, contain relatively higher frequency components. To composed affect of lekage capacitances of the electrodes while EMG singals recorded, negative input capacitance amplifiers are used.[3]

ECG channel signals are applied to a Wilson resistor bridge circuit, from which EKG derivations can be chosen. Analog multiplexer enables the user to choose one of the 12 ECG derivations or EMG.

Four 4-to-1 analog multiplexers (ADG 509F) are used to realize this multiplexing. The logic circuit that enables the user to choose the signal has been designed and realized separately.

To amplify the differential signals selectively and eliminate the common input signals, Burr Brown-INA 111 instrumentation amplifier is used. This amplifier has an input impedance about 10^{12} Ω and a CMRR of (minumum) 106 dB. Its gain is controlled by adjusting value of only one resistor. The gain is adjusted automatically in the set with the selection of ECG and EMG signal.

Right leg drive circuit is used to decrease the common mode signal by applying the same signal as a negative feedback to the input. It also limits the leakage currents since the leakage voltages will be subject to a high impedance. [3]

PS2501-1 opto-isolator circuit provides 5000Vrms isolation between patient circiuts and the display circuits.

Three filters have been realized in the set. The first one is the ECG filter and it is a 3rd order Butterworth type passband filter. It passes the frequencies between 0.05 Hz and 150 Hz. The second one is EMG filter. This filter is a second order Butterworth type 20-500Hz passband filter. The third filter is a Notch filter. It eliminates noise in the line frequencies, which is one of the most important problems in medical devices.

The output amplifier amplifies the filtered signals to the level of display devices. The 8255 interface which enables the user to see the output signals on a PC monitor .

3. Educational Features

To learn by doing is an important part of training. The aim in designing the set is to have an experiment set for a biomedical instrumentation laboratory with which students can learn by doing. The outputs of all blocks in the set have external connections, which can be used for experimental purposes.

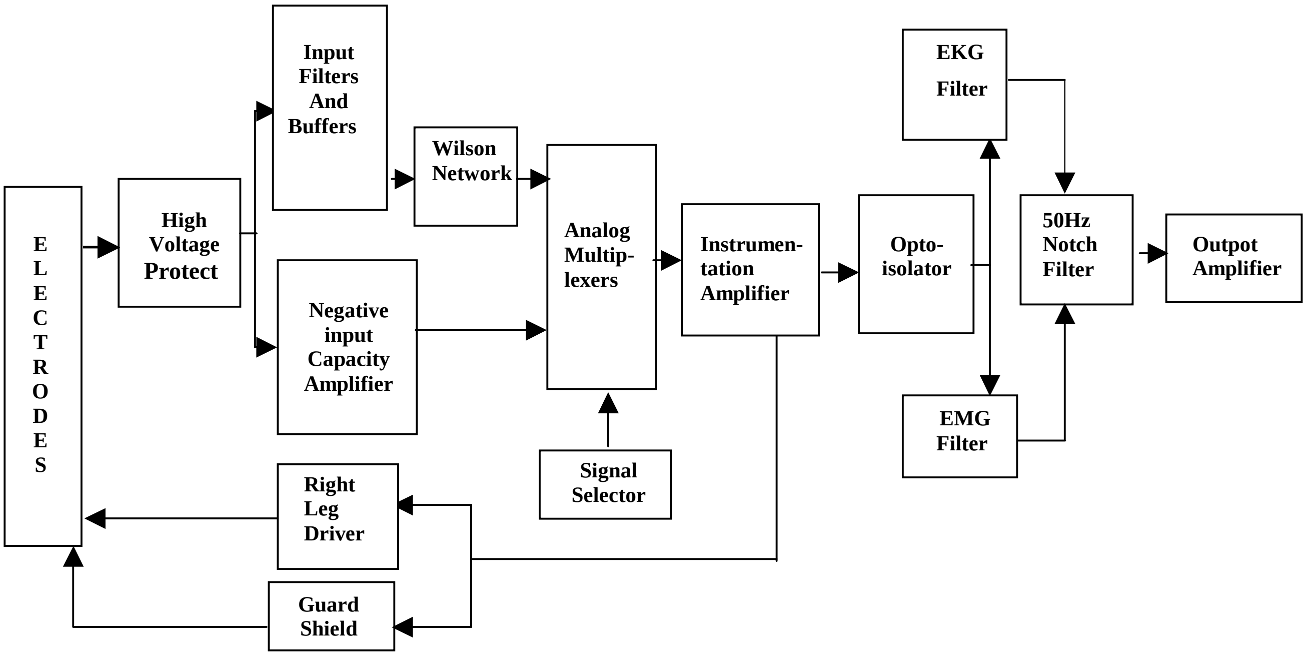

Figure 2. Block diagram of the instrumentation set realized[4]

Some of the experiments that can be done with the set are explained in the following paragraphs. Many other experiments can also be designed considering properties of the set.

Electrical safety experiments can be done with the set by measuring leakage currents between ground connection and instrument body, between instrument body and ground, between electrodes and ground, between electrodes.

Operation of neon lamps and voltage voltage limiting diods can be observed by applying defibrillator output to the high voltage protection circuit.

Another important application that can be realized with the set is to observe the filtering principles. This can be done by applying signals at various frequencies to the passive filters of the input blocks and the active filters at the ECG and EMG stages.

There are several second and third order filters in the set . Signals can be applied directly to these filters and output signals can be measured and observed. As the noise in line frequencies is one of the biggest problems in medical equipments, making measurements and observations on the notch filter is very beneficial for the students.

The buffer op-amps at the input stage and the op-amp amplifiers at the output stages can be utilized for teaching op-amps and their operational characteristics. Similarly, the instrumentation amplifiers can be used to observe how biopotential signals, which are mostly differential signals are amplified and how common mode signals are eliminated.

Experiments can be done on negative input capacitance amplifiers to learn methods used in compensating the leakage currents.

With the Wilson bridge in the set, principles of ECG and its derivations can be taught. The Right-leg drive circuit can be taught as one of the methods to eliminate common mode signals and to decrease the leakage current that will pass through the patient body.

Optical isolation principles can be taught with experiments and measurements on the optical isolation between patient circuits and the display circuits.

Analog multiplexer and signal selection circuits can be used in teaching how only one of the biological signals at the input is selected .

V. RESULTS

In this study, an experimental set which is used to select, display and process ECG and EMG signals has been introduced. All the signals at different levels of the block diagram can be observed on an oscilloscope. They can also be observed on a computer screen . The picture of the instrumentation set is shown in Figure-3.

1 mV- 80 bpm-ECG signal is generated by Netch Minisim patient simulator and is applied to the set. The output signals are observed on a HP54616B osciloscope. The output signals, derivations DI, DII and DIII are shown in Figure 4. EMG signals recorded from the "musculus brachioradialis" are shown in Figure 5.
A usage and experiment book for the instrumentation set is being prepared.

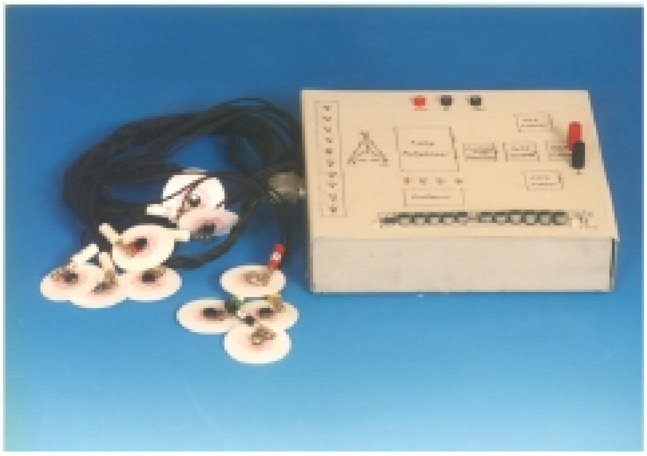

Figure 3. The picture of instrumentation set realized[4]

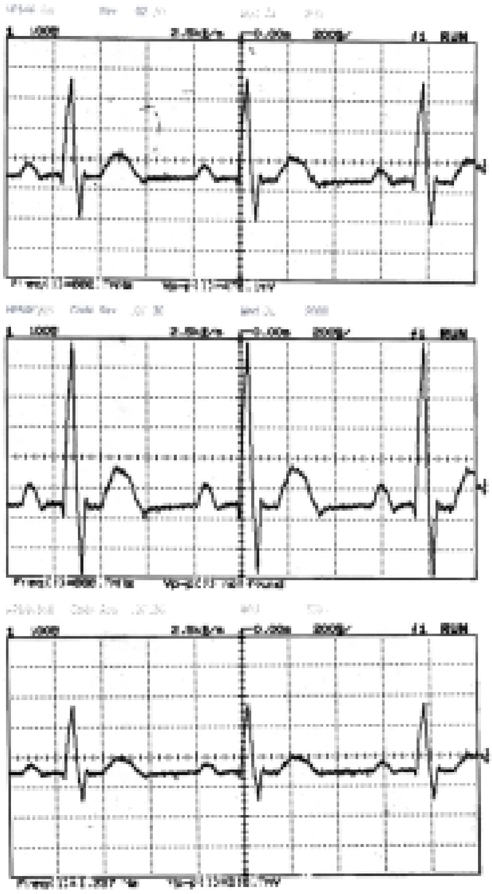

Figure 4. ECG signal outputs of the instrumentation set[4]

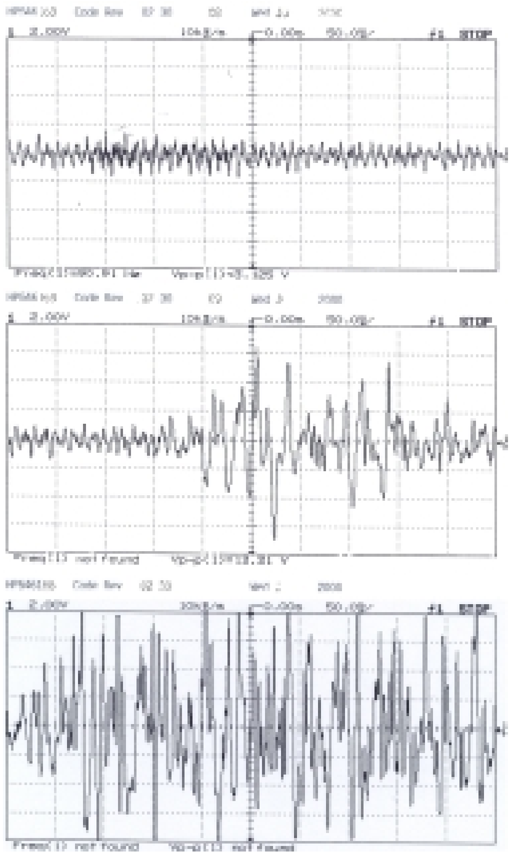

Figure-5: The EMG signals which show muscular activities and are recorded from the output of the instrumentation set [4]

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